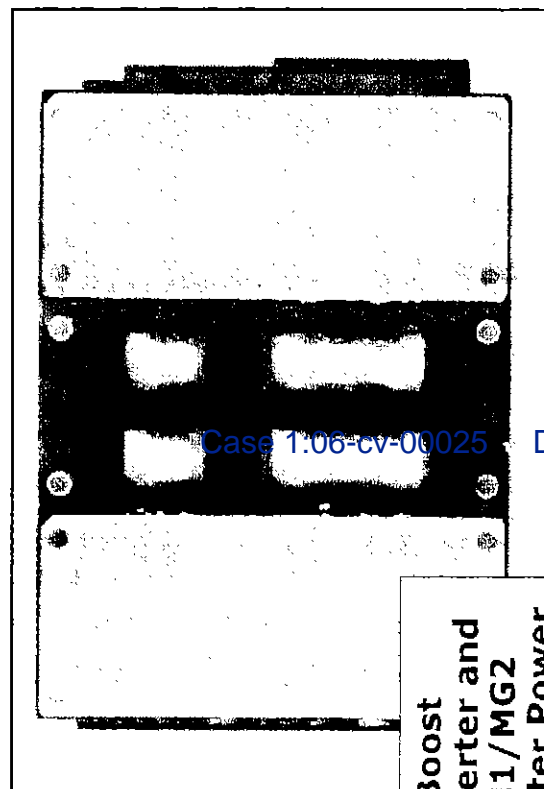
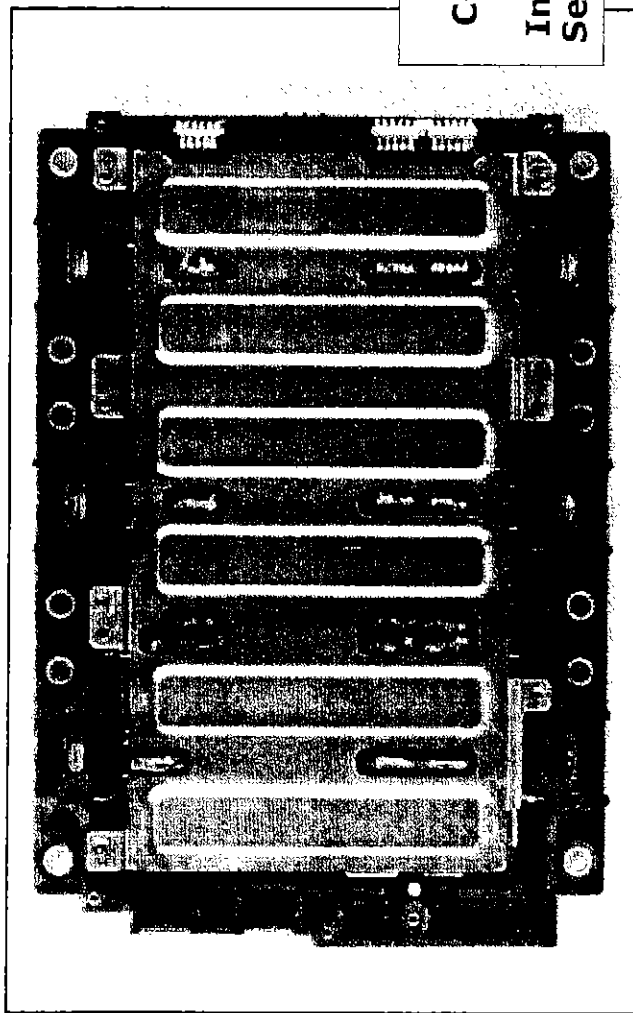
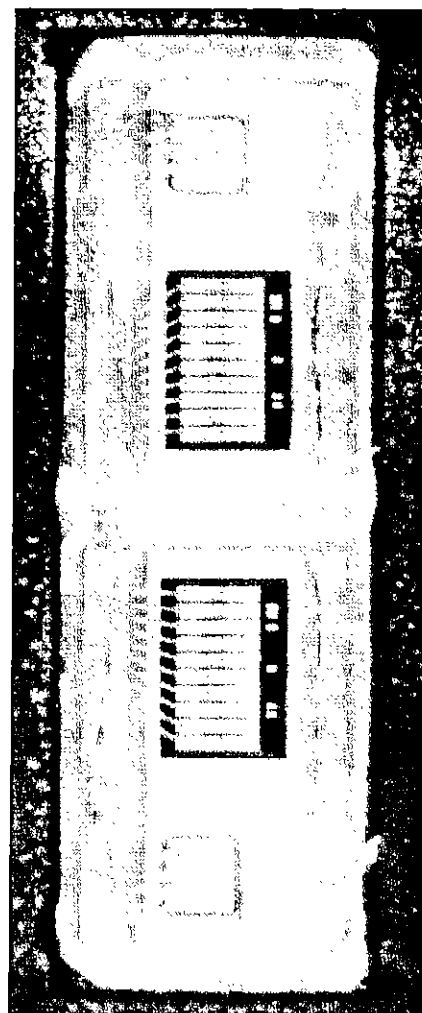
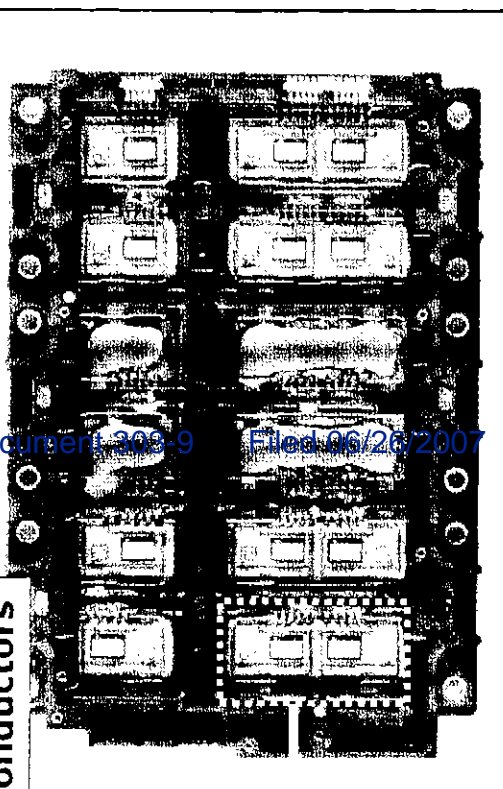


# Toyota Prius: Inverter/Converter Unit (ICU)



Boost  
Converter and  
MG1/MG2  
Inverter Power  
Semiconductors



Massive drive transistors and rectifier diodes.

# Skid Control Module (SCM)

The Prius' Skid Control Module (SCM) is a busy place in trying to control and correct a number of traction loss issues possible while driving. Working in concert with the Prius' Brake Control system, which drives the hydraulic friction braking and attempts to optimize use of regenerative braking as a fuel-saving measure, the SCM provides the smarts to tell each wheel exactly what to do when. Additionally, the SCM communicates closely with the drive train control electronics to modulate delivered power. Primary inputs to the SCM include the individual wheel-speed sensors, and the hydraulic pressure at the wheels' brake cylinder. Yaw, deceleration rate, and steering angle sensors are also inputs to the SCM used for tackling more complex vehicle stability control tasks.

Most of us have experienced the simplest case of traction control when we get a little overzealous with the accelerator on a slick road. While lighting up a set of tires may be fun, it's rarely safe and never an optimal way to deliver power to the pavement. Ask any drag racer and they'll tell you that minimizing wheel spin from the line and getting hooked-up is perhaps the biggest challenge of the craft. While the Prius powerplant pales in comparison to a 7000HP blown engine of a top-fuel drag racer, a wet or oily road is sometimes all it takes to lose traction from a stop, even with modest hybrid drivetrain power. The SCM here need only compare the rotation speed of the front (drive) wheels with that of the rear (undriven) wheels to detect simple wheel spin and back off on applied power to achieve front/rear wheel speed coherence.

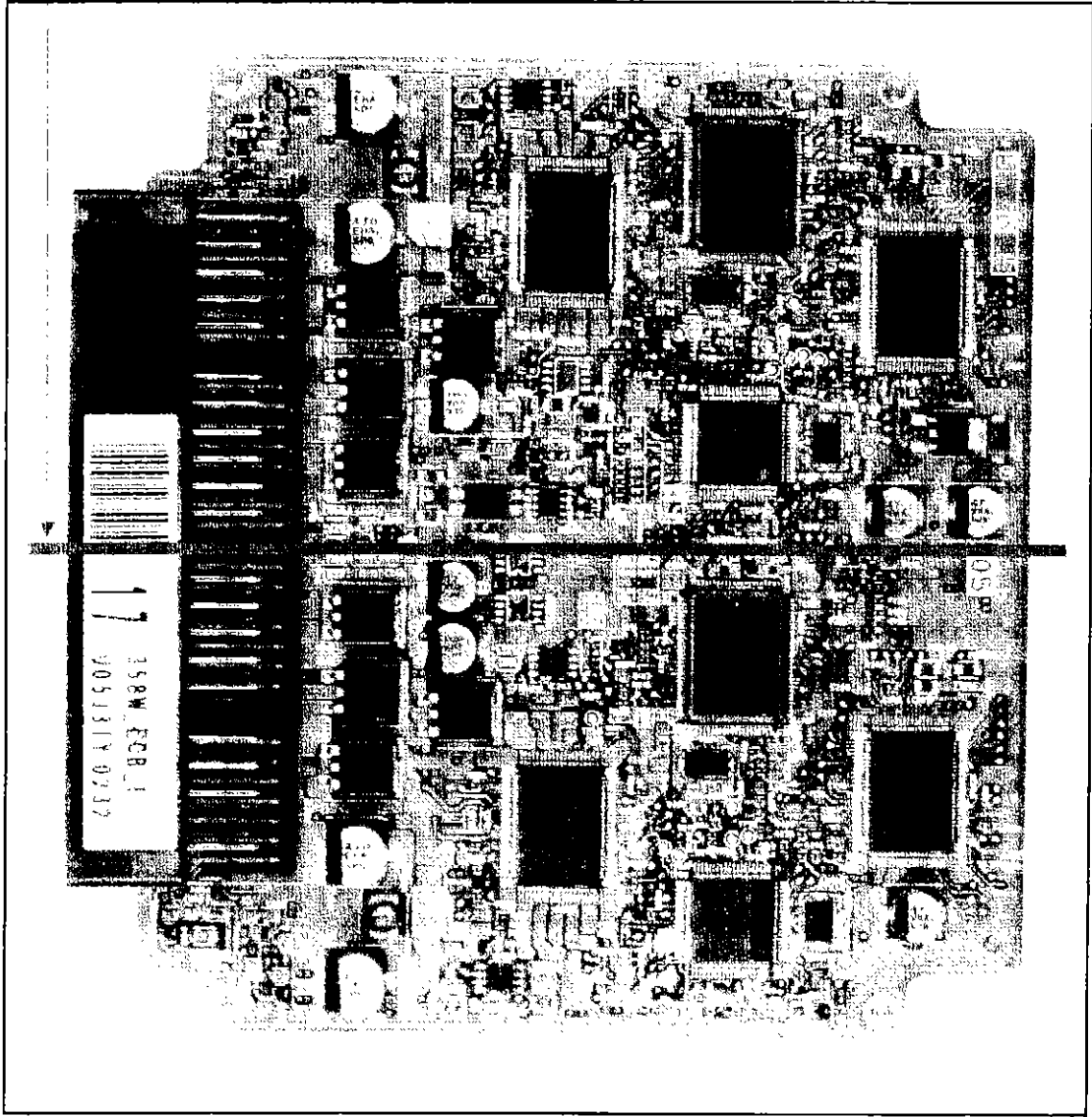
Another task for the SCM is dealing with – and preventing – wheel lockup during panic stops. Anti-lock Braking Systems (ABS) are an almost universal standard on cars these days and the SCM adds ABS chores to its list. Working somewhat in opposite to the suppression of wheelspin on starts, the SCM here again monitors wheel speed to be sure each is hauling it down to a stop at the same rate. As soon as the SCM detects a wheel (or wheels) locking up, it instructs the Brake Control system to suspend further application of braking force whether by regenerative or hydraulic means, to minimize skid and maximize braking effectiveness. As with starting, the best stops occur when the tire maintains traction. Having narrowly avoided a deer which bounded out in front of my own car recently, I certainly came to appreciate ABS a bit further. A badly-bent car, or worse, would have been a certainty if not for great brakes and great automatic brake modulation.

Overall traction and stability control are the last elements of the SCM's function. Understeer or oversteer, which result in the car "pushing" through an intended turn or back-end "spin-out" respectively, are usually not a good thing, and here again the SCM comes into play. By monitoring steering wheel angle, relative wheel speeds, yaw, and possibly lateral g-forces, the SCM can detect when either front wheel traction loss (understeer) or rear-wheel traction loss (oversteer) is imminent during turns. Again, the SCM works with the braking system to carefully direct applied braking forces at each of the four wheels to try and keep things under control.

Implementation of the SCM is conservative, as is the case of most mission-critical electronics we found in our Prius teardown. A meaty cast housing in the cabin and under the dash holds a single printed circuit board populated with peripherally-led IC device packages and spacious component layout. As shown in the picture, the SCM exhibits central symmetry, corresponding I suspect to the safety-minded control split of [front-right + left-rear] and [front-left + right rear] wheels. By implementing redundancy in this way, a partial failure still leaves one front wheel and one back wheel available for a SCM-driven controlled stop.

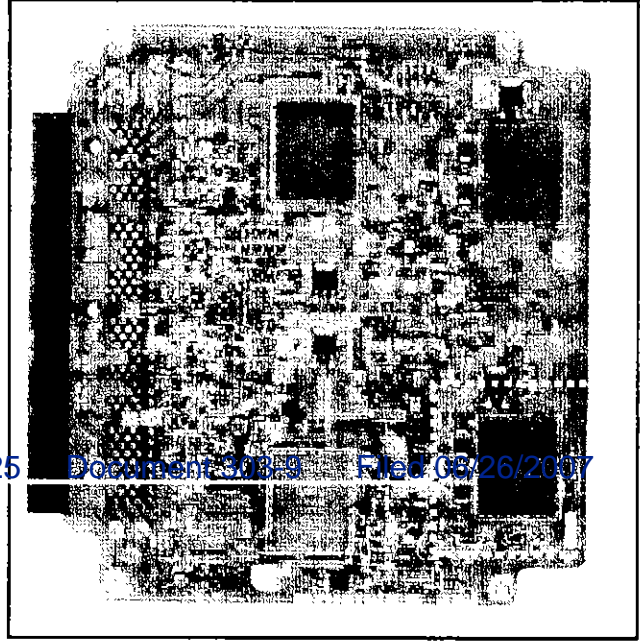
Analog circuits are key to the SCM implementation as input signal conditioning and output braking actuator drive are inherently non-digital tasks. The computational brains behind the SCM come from a Toyota-branded Toshiba #TMP1984FDG 32-bit Microprocessor and a Mitsubishi #M30620 16-bit Microprocessor, the latter showing maskworks with a 1995 copyright date. Again, conservative design seems to be the principle. Beyond the number crunching however, Toyota turned to custom devices for the mixed signal interfaces. A Toyota #DA023 and Toyota #DA034 are each analog control or conditioning devices based on a peek at the bare chip. No merchant-market foundry markings were seen on the die but there was a nice little Toyota logo located next to the part number on both chips.

While the backside of the circuit board is mostly void of components, the large control currents within the analog parts require attention to thermal management. The #DA023 and #DA034 chips, replicated on left and right sides, all have a thermal pad on the SCM board reverse side which carries heat away from the chips and makes contact into the SCM casing for keeping things cool.



Note symmetry / duplication  
about red center line

Thermal Pad to SCM Casing

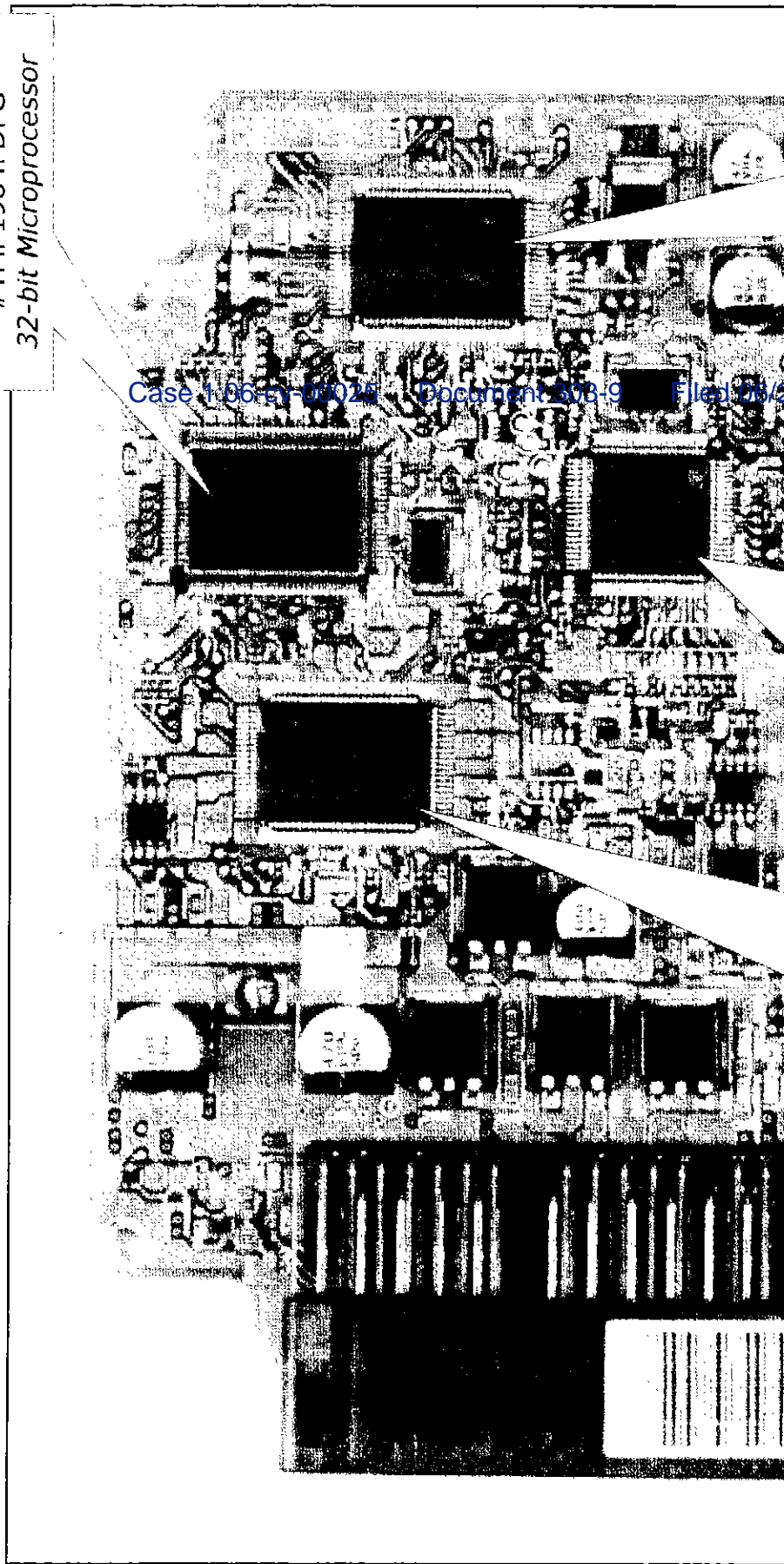


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**Toyota/Toshiba**  
#TMP1984FDFG  
32-bit Microprocessor

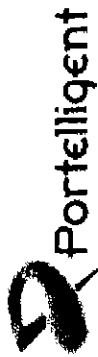


**Toyota**  
#DA034  
Power Control/Driver

**Mitsubishi**  
#M30620  
16-bit Microprocessor (95!)

**Toyota**  
#DA023  
Power Control

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# Airbag Control Module (ACM)

# Summary: Airbag Control

As with the ABS and traction control discussed in the previous section, airbags have become a fixture of automobiles. Federally mandated in U.S. cars sold after April 1, 1989, airbags provide a valuable and effective supplemental restraint system when used in combination with your normal seat belts. For those who have experienced an airbag deployment, you know that it is a violent event and costly to replace, so great care is built into the design of the Airbag Control Module (ACM) to insure it goes off when it needs to but doesn't deploy in a minor fender-bender. We manually fired off the airbag at the live ESC Prius Teardown to demonstrate the drama of an airbag event and because, well let's be honest, engineers just like to see things blow up sometimes. After getting a whiff of gunpowder and feeling the heat generated in deployment, we set off on looking at the electronics.

The Prius airbag system varies in complexity depending on whether optional side-impact airbag curtains are ordered. In the case of the primary driver side airbag located in the steering wheel, the ACM detects whether a collision of sufficient magnitude for deployment has occurred and also varies the degree of deployment to compensate for seating position. Those pulled up close to the wheel will not see the degree of deployment as those positioned further back.

Analog components form the critical front-end for the ACM, with accelerometers being the primary impact detection sensors. Two MEMS-based accelerometers made by Denso of Japan (#7Q 32 and #8T J8) are surface-mounted directly to the ACM board. The two MEMS components are placed orthogonal to one another, one in the Y-axis for front collision detection and the other oriented in the X axis and presumed to correspond to side-impact events. The sensors themselves are housed in a metal-lidded ceramic package and composed of two chips stacked on top of one another. The MEMS element appears to be a micromachined strain gauge which then connects to a second chip below for signal processing and communication with the rest of the ACM electronics.

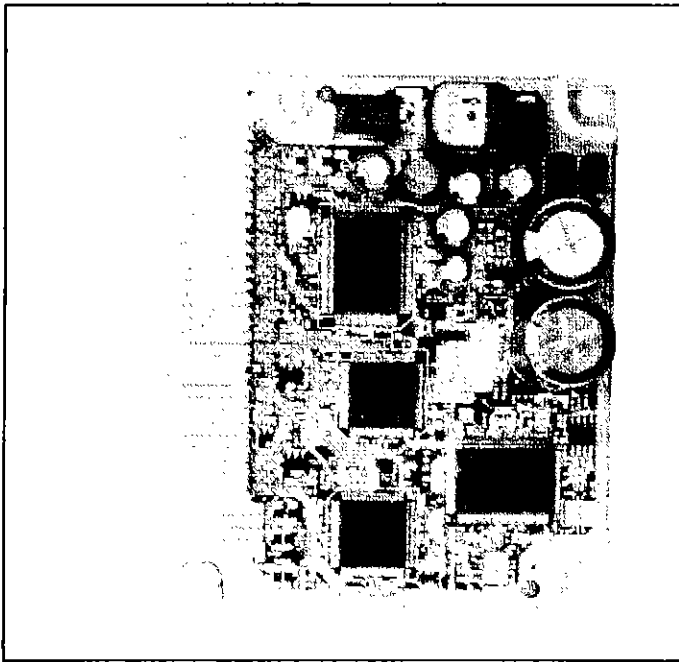
A small module (Toyota #09H29) containing a sliding mass which shorts out contacts with sufficient deceleration is also present. While we are not certain of its function, it could serve as the first line of impact detection to trigger activity in the balance of the ACM circuitry or perhaps serve as a backup sensor to the MEMS devices.

A Renesas #HD6432695 32-bit CPU w/ Memory monitors the MEMS outputs and performs the algorithmic computations to determine the fire/no-fire threshold and probably select the stage 1 or stage-2 deployment levels based on driver proximity. Most memory for the processor is resident on the Renesas chip and no discrete memory devices other than a small serial EEPROM are present.

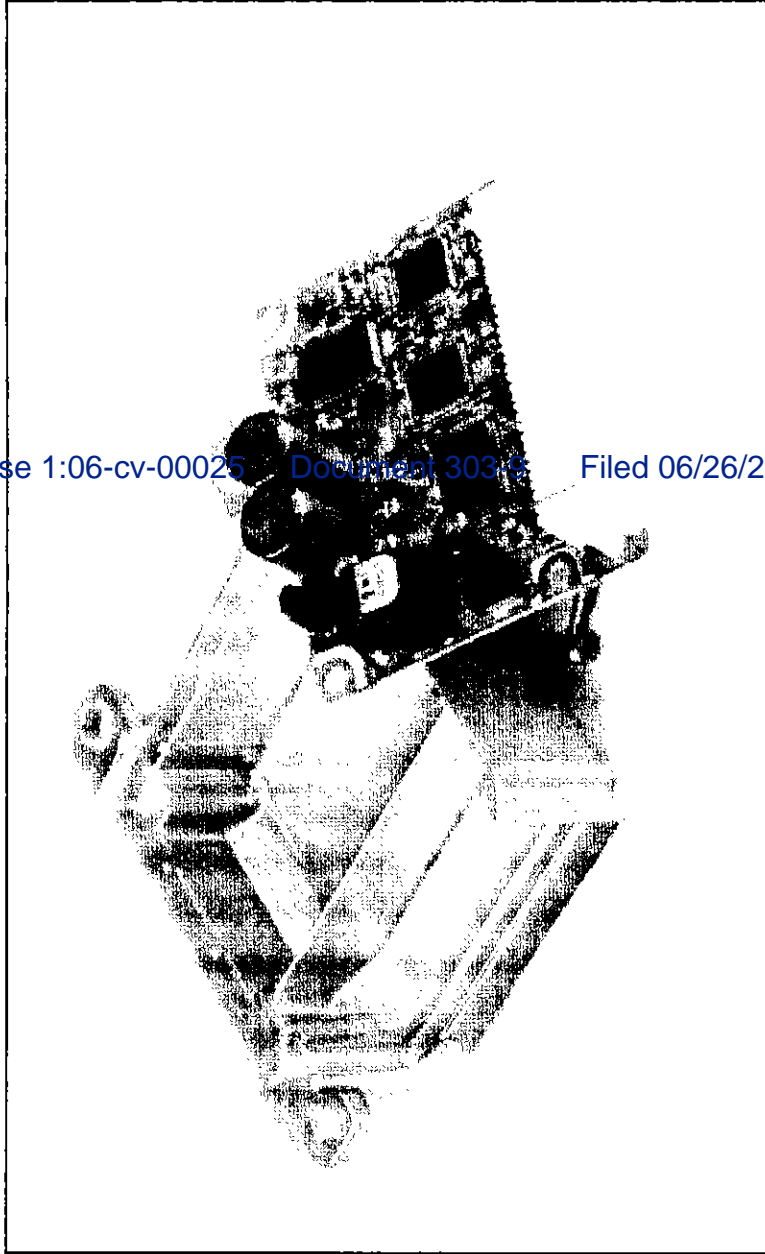
From there it is back to what appears as a more mixed-signal interface with three Denso-cu380m parts made by STMicro. The #151821-1390 numbered component is duplicated twice, leading to a possible conclusion that one affects the driver-side air bag module and the second the passenger-side airbag. The second Denso/STMicro part (#151821-136) is visually similar to the first pair of parts at the die level, perhaps a slight variation to handle communications control between the ACM and other Prius modules over the car's communication busses. Given the custom nature of the parts, precise details become hard to determine and I'm guessing here – reader input always welcome if you have some other thoughts. There were other airbag sensing modules in the car, probably used for side-curtain functions, so consider this module as only part of the total solution in the fully-optional Prius variant.

The ACM shown here was housed in yet another of the Prius' many cast metal module housings, using only compliant peripheral-leaded packages and an anti-corrosion varnish. As with many aspects of the Prius' constellation of electronics, the story on conservative design for safety and reliability of critical systems remains the same. In that vein, you will notice the two large electrolytic capacitors on the ACM. These too are probably a redundant safety element to assure enough local power for deployment in case the collision disrupts the SCM's normal 12V source of energy.

# Toyota Prius: Airbag Control Module (ACM)

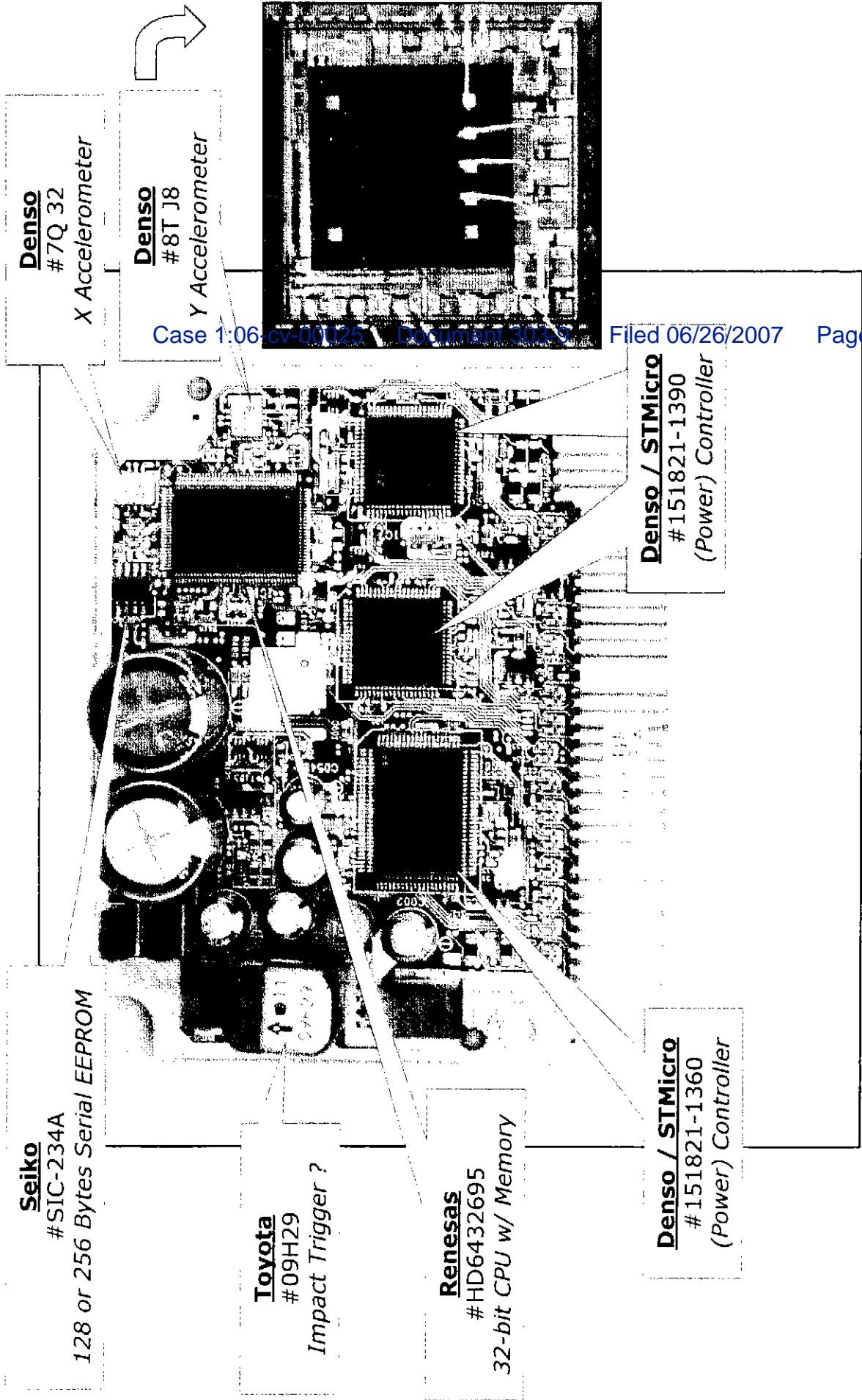


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# Toyota Prius: Airbag Control Module (ACM)



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# Dash Module



# Summary: Dash Module

While much of the vehicles status information and vehicle control functions comes by way of the central touch-screen panel, critical information is delivered from a dedicated display system visible directly behind the steering wheel. The Dash Module (DM) provides most of the output-only information such as speed, fuel-level, selected gear, and odometer/mileage by way of a digital readout and icon-based vacuum fluorescent display (VFD) panel.

Probably supplied here by Futaba or Noritake, the VFD technology has been around for quite some time, and Toyota has elected to shun the analog gauges used years ago and more recently back in fashion in favor of the numeric readout.

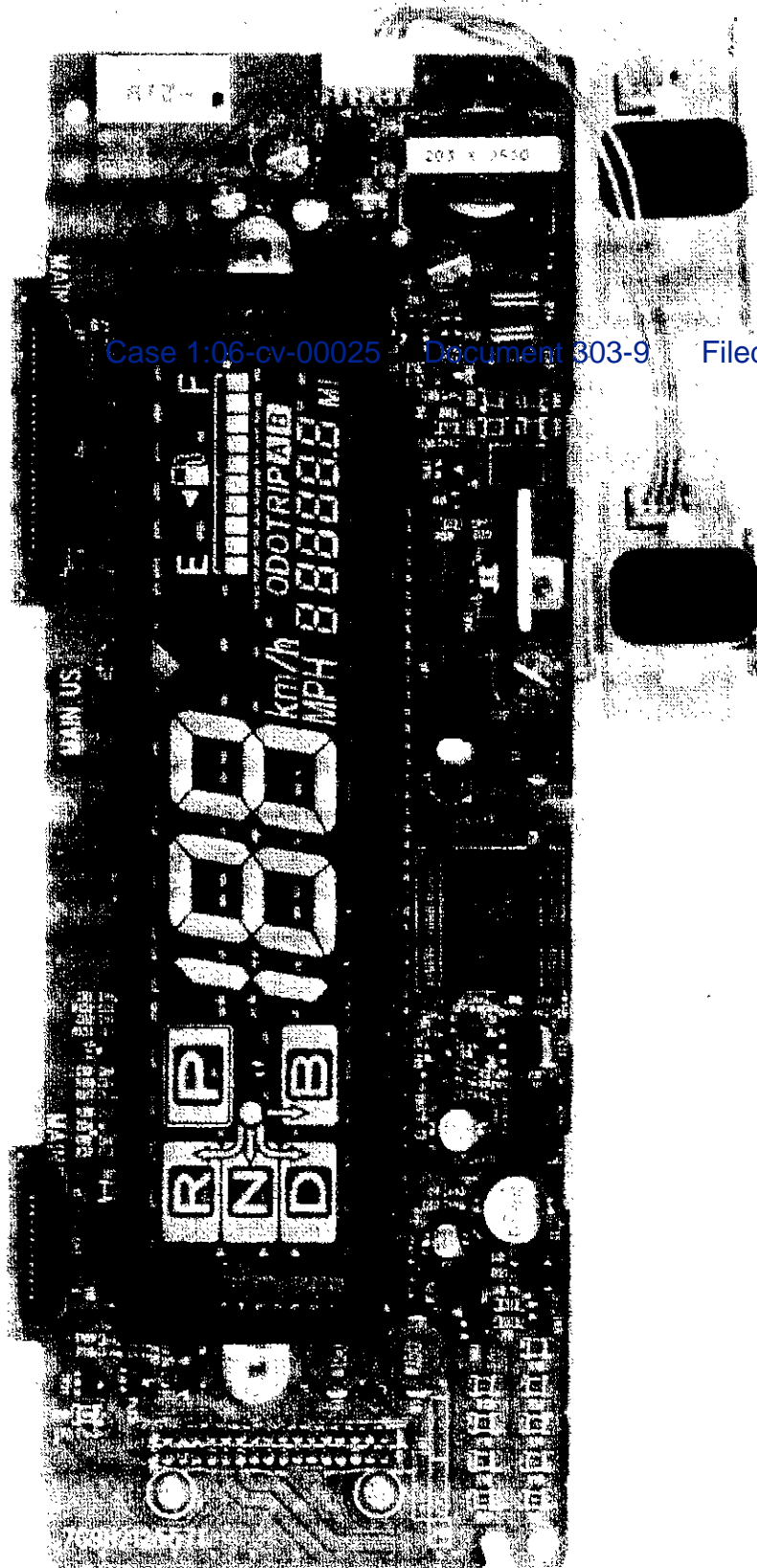
My first Casio calculator circa 1977 (yes, I took that apart too) used VFDs for their segment-based, high-contrast, high-visibility qualities. Readability and contrast are even more key in the automobile where harsh ambient sunlight might threaten legibility. To further improve visibility the driver actually sees a double-reflected image of the VFD rather than a direct view of the panel. Two mirrors on the underside of the dash direct the output of the VFD to the optical path of the driver, keeping stray light off of the VFD module itself and improving perceived viewing quality.

While not particularly high-current, the VFD does require high voltage, and an Oki Semiconductor #MSC1162A 40-bit VFD Display Driver translates output of the lone Fujitsu #MB90583C 16-Bit Microcontroller to the appropriate levels for achieving fluorescence from the driven electrodes of sealed vacuum chamber of the panel.

A 5-volt regulator, mystery Toshiba chip (clock?), and serial EEPROM are the primary remaining ICs on the DM board. Along with display control, the Fujitsu microprocessor forms the communications interface back to the gear-position sensor and engine control module. It is unclear whether speed and mileage information is calculated and stored within the DM itself or whether the DM serves strictly as a "dumb" display of information determined elsewhere in the Prius.

Two white modules connect into the DM as well, and here again a bit of "Huh?" factor set in. When opened up, the modules revealed an oil-damped V-shaped pendulum inside with the ends of the pendulum arms holding a magnet which swings overtop a Hall-effect sensor. My first thought was that these may form the yaw sensors mentioned earlier in the context of the Skid Control Module, but the slow damping would tend to rule that out. Perhaps a more likely use given their construction, tie-in to the DM circuits, and their orthogonal arrangement when mounted is a tilt sensor for compensating displayed fuel level. When parked at an angle in one or both the axes of the car, the sensors might be used to recalibrate displayed fuel level so that accurate tank readings are possible even when gas in the tank is piled up away from the in-tank level gauge. Again, with the complexity of the car it all gets a bit hard to sort out sometimes.

# Toyota Prius: Dash Module (DM)

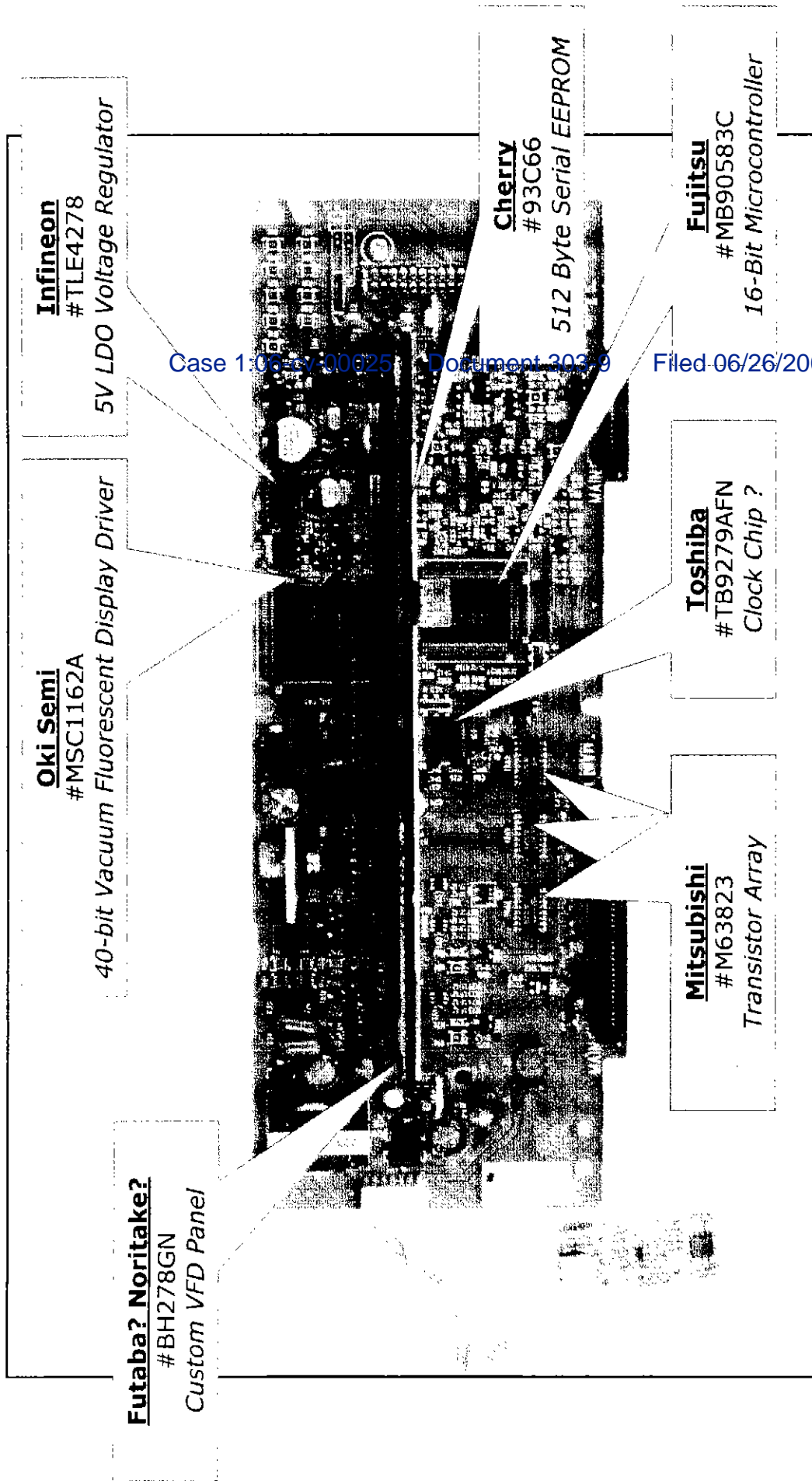


What you see from behind the wheel.....

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# Toyota Prius: Dash Module (DM)



Mostly a display and display alone – limited direct input.





# Portelligent Summary: User Interface & Navigation

With increasing frequency, car buyers are coming to spend big for the convenience of in-car navigation. Not unusual for factory-optional navigation, the Prius' GPS-based mapping and guidance system adds almost \$US2000 to the total Prius sticker-price.

As a practical matter, what the driver perceives as the navigation "system" is really a composition of two distinct sub-systems, one the GPS navigation unit itself and the other a visual interface by which the driver can see and interact with mapping functions.

The Prius' visual user interface (VUI) comes by way of a Toshiba liquid crystal display (LCD) and associated electronics located mid-dash. The touch-screen LCD panel is an important and standard part of any Prius bought today (it's present even if the navigation option is not chosen), serving as the interface for energy monitoring, climate control, and car audio. Like a general trend in cars (and aircraft) today, much of the traditional gauge and button UI is migrating to a centralized "glass cockpit" and the Prius is no exception.

Within the VUI, communication with the ECM, HVECU, and other convenience control subsystems occurs, allowing the touch panel to serve many roles depending on the selected use mode chosen by way of select buttons to either side of the LCD. While speed, gear, fuel-level, and odometer functions are delivered via a vacuum-fluorescent display Dash Module (DM) assembly just discussed, the bulk of interaction in the Prius comes through the VUI. A pair of components based on the multi-OS capable "Naviem" partnership between Denso and Toshiba creates the master graphical display and control interface. 32MB of NOR flash from Sharp and 64MB of DDR SDRAM from Elpida join with the Naviem devices to create what can be considered the general-purpose compute system responsible for touch-screen LCD and monitoring/command I/O. The VUI box is cooled by a pair of fans, hinting at the relative processor horsepower within.

Pony up the extra money for navigation unit (NU), and the MAP/Voice and DEST mode buttons become active alongside the standard VUI mode selects. With the navigation option, a new box housing the navigation-specific electronics and accompanying DVD-ROM drive for map data gets installed under the driver's seat at build-time. The factory navigation unit supports not just mapping information however. Voice recognition allows hands-free address and navigation command entry and voice prompts – like many commercial GPS units – provide spoken driving directions among other functions.

The navigation subsystem is standalone other than the lack of the visual interface. To complete the connection to the VUI for visual aspects of operation, a Sony Gigabit Video Interface Transmitter (#CXB1457R) pipes data up to the VUI for display. A corresponding Sony #CXB1458R Gigabit Video Interface Receiver is found within the VUI box to bring in navigation unit information for display. Map data is available by way of a Panasonic-manufactured DVD-ROM drive housed within the NU enclosure.

A GPS antenna installed under the dash cover is positioned to allow line-of-sight to GPS satellites through the front windshield, and a coax cable then snakes its way back to the underseat navigation box. The RF front end for GPS is a quite-small portion of the navigation electronics, based here on a Panasonic #AN18401A down-converter to get to a de-modulated GPS input signal. From there, a sizable Rensesas #HD6473810 processor is responsible for all of the GPS baseband work needed to calculate present position for joining with local mapping data. But GPS data-crunching is only part of the required processor function since all of the voice recognition and voice prompting is also done in the NU and it is here that the processor demands rise beyond GPS alone.

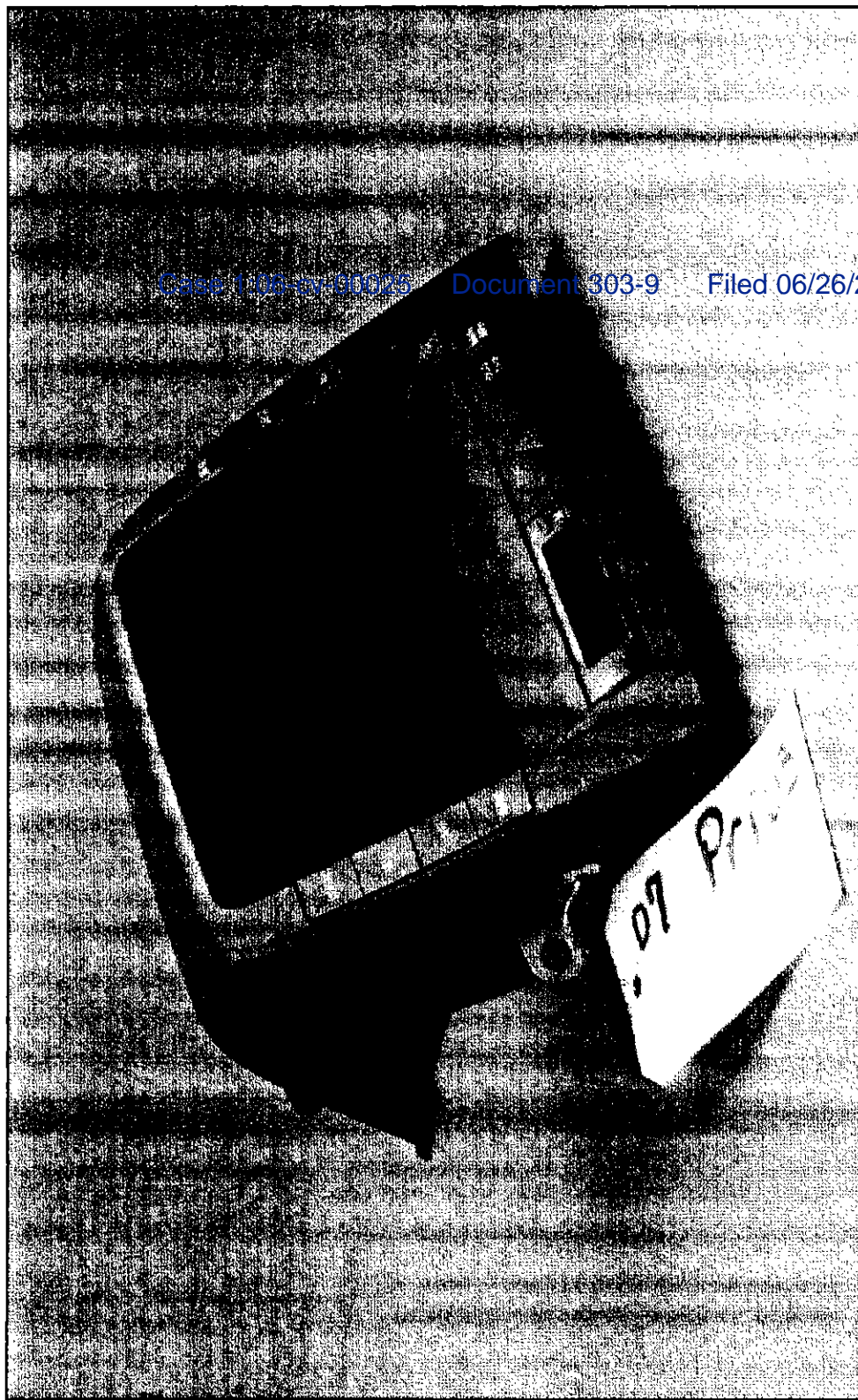
Within the NU, 96MB of total DDR SDRAM is found spread across three 32MB Elpida chips and 1MB of Spansion NOR flash serves for local code store. It's worth noting that both the NU and VUI which form the total navigation solution are some of the few modules in the Prius which use sizable stores of discrete memory versus the much smaller embedded/on-chip memory of other processor subsystems. Likewise IC packaging steps up to high pin-count BGA devices over the QFP packaging found in the more conservatively-designed modules such as ECM, HVECU, and ICU assemblies discussed elsewhere.

A mix of cabin-internal use environments, more modern design, and less-mission-critical attributes for the NU and VUI probably contribute to the latter's closer engineering resemblance to traditional consumer electronics. It is here in the Infotainment area where we indeed see much of the growth in automotive electronics and convergence with the gadgetry we're more accustomed to seeing outside the car.

# Visual User Interface (VUI)



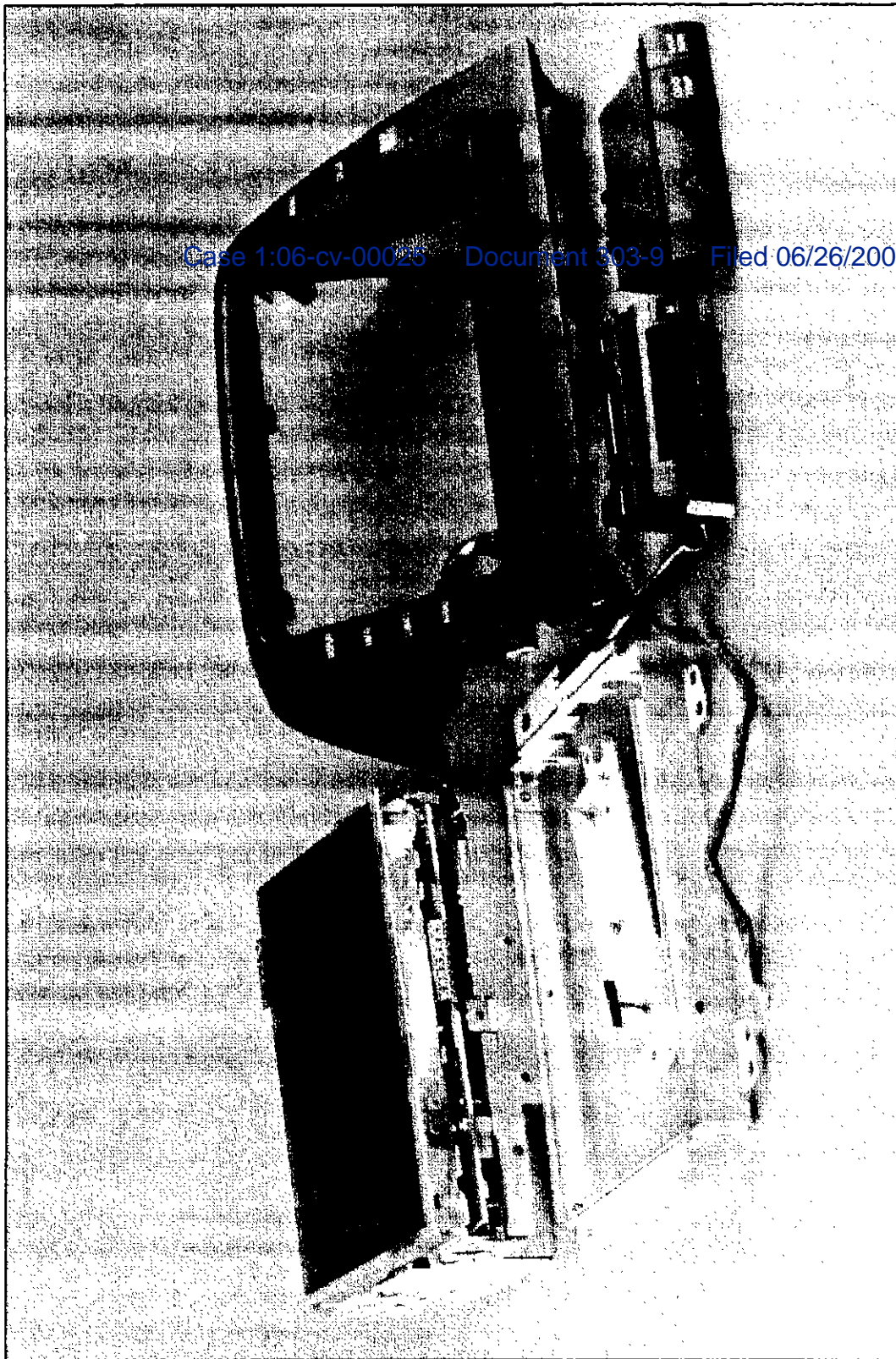
# Toyota Prius: *Visual User Interface (VUI)*



The central touch-screen interface for Nav, Trip Computer, Audio, Maintenance, Power Train Status, Climate Control / HVAC

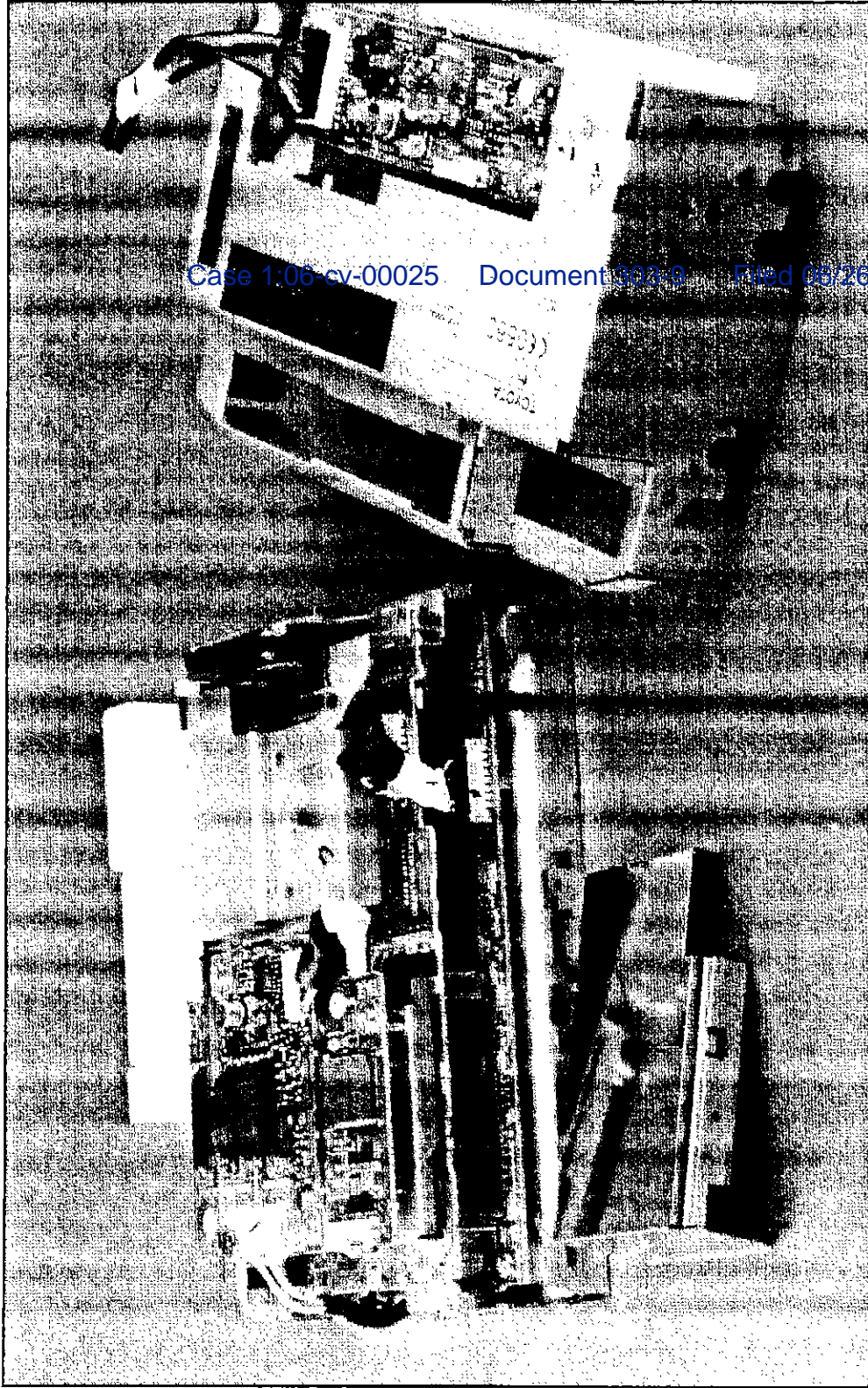


# Toyota Prius: *Visual User Interface (VUI)*



Switch Module, Clock Module separate from the core display/processor assembly.

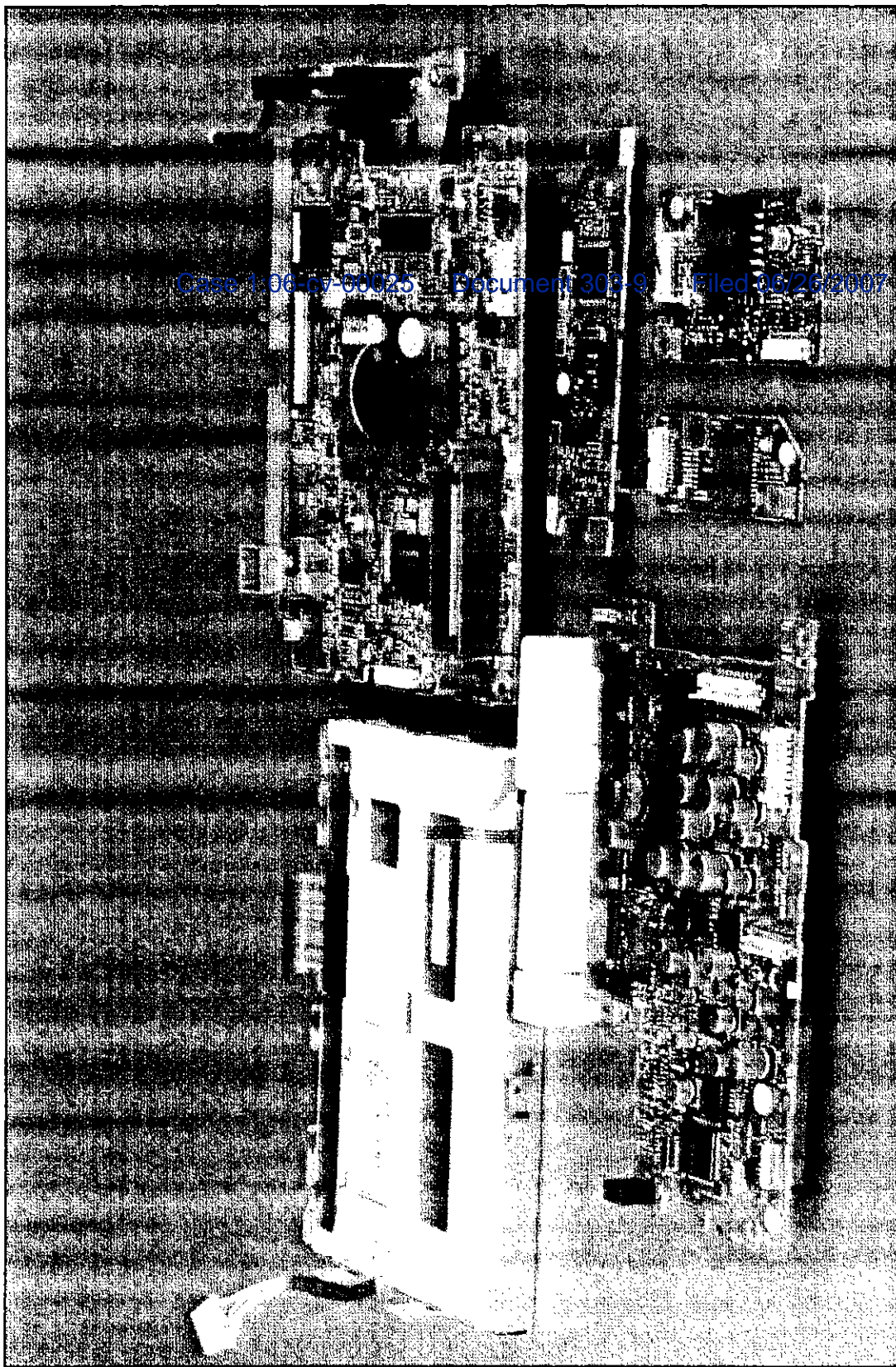
# Toyota Prius: *Visual User Interface (VUI)*



Lots of mechanical chassis to bring together multiple PCB assemblies and LCD panel.



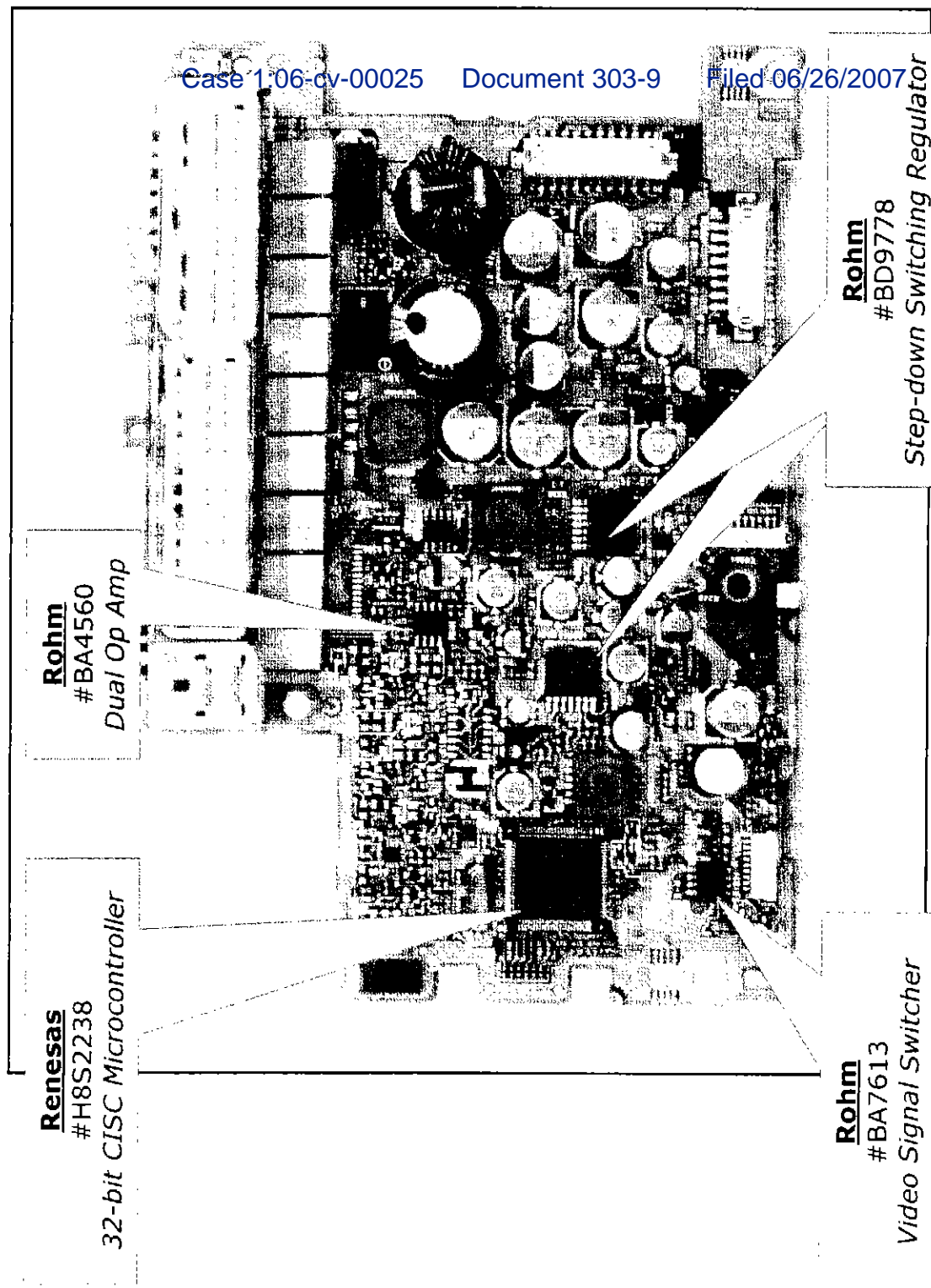
# Toyota Prius: *Visual User Interface (VUI)*



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# Toyota Prius: Visual User Interface (VUI)



I/O controller and DC-DC conversion here along with New Unit Input